The Silicate Class

The silicates are the largest, the most interesting and the most complicated class of minerals by far. Approximately 30% of all minerals are silicates and some geologists estimate that 90% of the Earth's crust is made up of silicates. With oxygen and silicon the two most abundant elements in the earth's crust silicates abundance is no real surprise.

The basic chemical unit of silicates is the (**SiO_4**) tetrahedron shaped anionic group with a negative four charge (-4). The central silicon ion has a charge of positive four while each oxygen has a charge of negative two (-2) and thus each silicon-oxygen bond is equal to one half (1/2) the total bond energy of oxygen. This condition leaves the oxygens with the option of bonding to another silicon ion and therefore linking one (**SiO_4**) tetrahedron to another and another, etc..

The complicated structures that these silicate tetrahedrons form is truly amazing. They can form as single units, double units, chains, sheets, rings and framework structures. The different ways that the silicate tetrahedrons combine is what makes the Silicate Class the largest, the most interesting and the most complicated class of minerals.

The Silicates are divided into the following subclasses, not by their chemistries, but by their *structures*:

- **Nesosilicates** *(single tetrahedrons)*
- **Sorosilicates** *(double tetrahedrons)*
- **Inosilicates** *(single and double chains)*
- **Cyclosilicates** *(rings)*
- **Phyllosilicates** *(sheets)*
- **Tectosilicates** *(frameworks)*

The Nesosilicate Subclass (single tetrahedrons)

The simplest of all the silicate subclasses, this subclass includes all silicates where the (**SiO_4**) tetrahedrons are unbonded to other tetrahedrons. In this respect they are similar to other mineral classes such as the **sulfates** and **phosphates**. These other classes also have tetrahedral basic ionic units (**PO_4** & **SO_4**) and thus there are several groups and minerals within them that are similar to the members of the nesosilicates. Nesosilicates, which are sometimes referred to as orthosilicates, have a structure that produces stronger bonds and a closer packing of ions and therefore a higher density, index of refraction and hardness than chemically similar silicates in other subclasses. Consequently, There are more **gemstones** in the nesosilicates than in any other silicate subclass. Below are the more common members of the nesosilicates. See the **nesosilicates'** page for a more complete list.

- **Andalusite** *(Aluminum Silicate)*
- **Chloritoid** *(Iron Magnesium Manganese Aluminum Silicate Hydroxide)*
- **Datolite** *(Calcium Boro-Silicate Hydroxide)*
- **Euclase** *(Beryllium Aluminum Silicate Hydroxide)*
- **Fayalite** *(Iron Silicate)*
- **Fosterite** *(Magnesium Silicate)*
- **Gadolinite** *(Yttrium Iron Beryllium Silicate)*
- **The Garnet Group:**
  - **Almandine** *(Iron Aluminum Silicate)*
  - **Andradite** *(Calcium Iron Silicate)*
  - **Grossular** *(Calcium Aluminum Silicate)*
  - **Pyrope** *(Magnesium Aluminum Silicate)*
  - **Spessartine** *(Manganese Aluminum Silicate)*
  - **Uvarovite** *(Calcium Chromium Silicate)*
- **Howlite** *(Calcium Boro-Silicate Hydroxide)*
- **Humite** *(Magnesium Iron Silicate Fluoride Hydroxide)*
- **Kyanite** *(Aluminum Silicate)*
- **Olivine** *(Magnesium Iron Silicate)*
- **Phenakite** *(Berylium Silicate)*
- **Sillimanite** *(Aluminum Silicate)*
- **Sphene or Titanite** *(Calcium Titanium Silicate)*
- **Staurolite** *(Iron Magnesium Zinc Aluminum Silicate Hydroxide)*
- **Thorite** *(Thorium Uranium Silicate)*
- **Topaz** *(Aluminum Silicate Fluoride Hydroxide)*
- **Uranophane** (*Hydrated Calcium Uranyl Silicate)*
- **Willemite** *(Zinc Silicate)*
- **Zircon** *(Zirconium Silicate)*

The Sorosilicate Subclass (double tetrahedrons)

Sorosilicates have two silicate tetrahedrons that are linked by one oxygen ion and thus the basic chemlcal unit is the anion group (Si2O7) wlth a negative six charge (-6). This structure forms an unusual hourglass-like shape and it may be due to this oddball structure that this subclass is the smallest of the silicate subclasses. It includes minerals that may also contain normal sillcate tetrahedrons as well as the double tetrahedrons. The more complex members of this group, such as Epidote, contain chains of aluminum oxide tetrahedrons being held together by the individual silicate tetrahedrons and double tetrahedrons. Most members of this group are rare, but epldote is widespread in many metamorphic environments. Below are the more common members of the sorosilicates. See the **sorosilicates'** page for a more complete list.

- **Bertrandite** *(Beryllium Silicate Hydroxide)*
- **Danburite** *(Calcium Boro-Silicate)*
- **The Epidote group**
  - **Allanite (***Yttrium Cerium Calcium Aluminum Iron Silicate Hydroxide)*
  - **Clinozoisite** *(Calcium Aluminum Silicate Hydroxide)*
  - **Epidote** *(Calcium Iron Aluminum Silicate Hydroxide)*

- **Zoisite** *(Calcium Aluminum Silicate Hydroxide)*
- **Hemimorphite** *(Hydrated Zinc Silicate Hydroxide)*
- **Ilvaite** *(Calcium Iron Silicate Hydroxide)*
- **Idocrase or Vesuvianite** *(Calcium Magnesium Aluminum Silicate Hydroxide)*

The Inosilicate Subclass (single and double chains)

This subclass contains two distinct groups: the single chain and double chain silicates. In the **single chain** group the tetrahedrons share two oxygens with two other tetrahedrons and form a seemingly endless chain. The ratio of silicon to oxygen is thus 1:3. The tetrahedrons alternate to the left and then to the right along the line formed by the linked oxygens although more complex chains seem to spiral. In cross section the chain forms a trapezium and this shape produces the angles between the crystal faces and cleavage directions.

In the **double chain** group, two single chains lie side by side so that all the right sided tetrahedrons of the left chain are linked by an oxygen to the left sided tetrahedrons of the right chain. The extra shared oxygen for every four silicons reduces the ratio of silicons to oxygen to 4:11. The double chain looks like a chain of six sided rings that might remind someone of a child's clover chain. The cross section is similar in the double chains to that of the single chains except the trapezium is longer in the double chains. This difference produces a difference in angles. The cleavage of the two groups results between chains and does not break the chains thus producing prismatic cleavage. In the single chained silicates the two directions of cleavage are at nearly right angles (close to 90 degrees) forming nearly square cross sections. In the double chain silicates the cleavage angle is close to 120 and 60 degrees forming rhombic cross sections making a convenient way to distinguish double chain silicates from single chain silicates. Below are the more common members of the inosilicates. See the **Inosilicates'** page for a more complete list.

Single Chain Inosilicates:

- **Lorenzenite** *(Sodium Titanium Silicate)*
- **Neptunite** *(Potassium Sodium Lithium Iron Manganese Titanium Silicate)*
- **Okenite** *(Hydrated Calcium Silicate)*
- **Pectolite** *(Sodium Calcium Silicate Hydroxide)*
- The **Pyroxene Group**:
  - **Aegirine** *(Sodium Iron Silicate)*
  - **Augite** *(Calcium Sodium Magnesium Aluminum Iron Titanium Silicate)*
  - **Diopside** *(Calcium Magnesium Silicate)*
  - **Enstatite** *(Magnesium Silicate)*
  - **Hedenbergite** *(Calcium Iron Silicate)*
  - **Hypersthene** *(Magnesium Iron Silicate)*
  - **Jadeite** *(Sodium Aluminum Iron Silicate)*
  - **Spodumene** *(Lithium Aluminum Silicate)*
- **Rhodonite** *(Manganese Iron Magnesium Calcium Silicate)*
- **Serandite** *(Sodium Manganese Calcium Silicate Hydroxide)*
- **Shattuckite** *(Copper Silicate Hydroxide)*
- **Wollastonite** *(Calcium Silicate)*

The Double Chain Inosilicates:

- The **Amphibole Group**:
  - **Actinolite** *(Calcium Magnesium Iron Silicate Hydroxide)*
  - **Anthophyllite** *(Magnesium Iron Silicate Hydroxide)*
  - **Cummingtonite** *(Iron Magnesium Silicate Hydroxide)*
  - **Edenite** *(Sodium Calcium Magnesium Iron Aluminum Silicate Hydroxide)*
  - **Hornblende** *(Calcium Sodium Magnesium Iron Aluminum Silicate Hydroxide)*
  - **Riebeckite** *(Sodium Iron Silicate Hydroxide)*
  - **Tremolite** *(Calcium Magnesium Iron Silicate Hydroxide)*
- **Astrophyllite** *(Potassium Iron Titanium Silicate Hydroxide)*
- **Babingtonite** *(Calcium Iron Manganese Silicate Hydroxide)*
- **Inesite** *(Hydrated Calcium Manganese Silicate Hydroxide)*

The Cyclosilicate Subclass (rings)

These silicates form chains such as in the **inosilicates** except that the chains link back around on themselves to form rings. The silicon to oxygen ratio is generally the same as the inosilicates, (1:3). The rings can be made of the minimum three tetrahedrons forming triangular rings (such as in benitoite). Four tetrahedrons can form a rough square shape (such as in axinite). Six tetrahedons form hexagonal shapes (such as in beryl, cordierite and the tourmalines). There are even eight membered rings and more complicated ring structures. The symmetry of the rings usually translates directly to the symmetry of these minerals; at least in the less complex cyclosilicates. Benitoite's ring is a triangle and the symmetry is **trigonal** or three-fold. Beryl's rings form hexagons and its symmetry is **hexagonal** or six-fold. The Tourmalines' six membered rings have alternating tetrahedrons pointing up then down producing a trigonal as opposed to an hexagonal symmetry. Axinite's almost total lack of symmetry is due to the complex arrangement of its square rings, triangle shaped borate anions (BO3) and the position of OH groups. Cordierite is pseudo-hexagonal and is analogous to beryl's structure except that aluminums substitute for the silicons in two of the six tetrahedrons. There are several **gemstone** minerals represented in this group, a testament to the general high hardness, luster and durability. Below are the more common members of the cyclosilicates. See the **Cyclosilicates'** page for a more complete list.

- **Axinite** *(Calcium Magnesium Iron Manganese Aluminum Borosilicate Hydroxide)*
- **Baratovite** *(Potassium Lithium Calcium Titanium Zirconium Silicate Fluoride)*
- **Benitoite** *(Barium Titanium Silicate)*
- **Beryl** *(Berylium Aluminum Silicate)*
- **Cordierite** *(Magnesium Aluminum Silicate)*
- **Dioptase** *[Copper Silicate Hydroxide]*
- **Eudialyte** *(Sodium Calcium Cesium Iron Manganese Zirconium Silicate Hydroxide Chloride)*
- **Milarite** *(Hydrated Potassium Calcium Aluminum Beryllium Silicate)*
- **Osumilite** *(Potassium Sodium Iron Magnesium Aluminum Silicate)*
- **The Tourmaline Group:**
  - **Dravite** *(Sodium Magnesium Aluminum Boro-Silicate Hydroxide)*
  - **Elbaite** *(Sodium Lithium Aluminum Boro-Silicate Hydroxide)*

- **Schorl** *(Sodium Iron Aluminum Boro-Silicate Hydroxide)*
- **Uvite** *(Calcium Sodium Iron Magnesium Aluminum Boro-Silicate Hydroxide)*
- **Sugilite** *(Potassium Sodium Lithium Iron Manganese Aluminum Silicate)*

The Phyllosilicate Subclass (sheets)

In this subclass, rings of tetrahedrons are linked by shared oxygens to other rings in a two dimensional plane that produces a sheet-like structure. The silicon to oxygen ratio is generally 1:2.5 (or 2:5) because only one oxygen is exclusively bonded to the silicon and the other three are half shared (1.5) to other silicons. The symmetry of the members of this group is controlled chiefly by the symmetry of the rings but is usually altered to a lower symmetry by other ions and other layers. The typical crystal habit of this subclass is therefore flat, platy, book-like and display good basal cleavage. Typically, the sheets are then connected to each other by layers of cations. These cation layers are weakly bonded and often have water molecules and other neutral atoms or molecules trapped between the sheets. This explains why this subclass produces very soft minerals such as talc, which is used in talcum powder. Some members of this subclass have the sheets rolled into tubes that produce fibers as in asbestos serpentine.
Below are the more common members of the phyllosilicates. See the **Phyllosilicates'** page for a more complete list.

- **Apophyllite** *(Hydrated Potassium Sodium Calcium Silicate Hydroxide Fluoride)*
- **Cavansite** *(Hydrated Calcium Vanadium Silicate)*
- **Chrysocolla** *(Hydrated Copper Aluminum Hydrogen Silicate Hydroxide)*
- **The Clay Group:**
  - **The Chlorite Group:**
    - **Chlorite** *(Iron Magnesium Aluminum Silicate Hydroxide)*
    - **Clinochlore** (the chromium variety **kaemmererite)** *(Iron Magnesium Aluminum Silicate Hydroxide)*
    - **Cookeite** *(Lithium Aluminum Silicate Hydroxide)*
  - **Kaolinite** *(Aluminum Silicate Hydroxide)*
  - **Pyrophyllite** *(Aluminum Silicate Hydroxide)*
  - **Talc** *(Magnesium Silicate Hydroxide)*
- **Gyrolite** *[Hydrated Calcium Silicate hydroxide]*
- The **Mica Group:**
  - **Biotite** *(Potassium Iron Magnesium Aluminum Silicate Hydroxide Fluoride)*
  - **Lepidolite** *(Potassium Lithium Aluminum Silicate Hydroxide Fluoride)*
  - **Muscovite** *(Potassium Aluminum Silicate Hydroxide Fluoride)*
  - **Phlogopite** *(Potassium Magnesium Aluminum Silicate Hydroxide Fluoride)*
  - **Zinnwaldite** *(Potassium Lithium Aluminum Silicate Hydroxide Fluoride)*
- **Prehnite** *(Calcium Aluminum Silicate Hydroxide)*
- **Serpentine** *(Iron Magnesium Silicate Hydroxide)*

The Tectosilicate Subclass (frameworks)

This subclass is often called the "Framework Silicates" because its structure is composed of interconnected tetrahedrons going outward in all directions forming an intricate framework analogous to the framework of a large building. In this subclass all the oxygens are shared with other tetrahedrons giving a silicon to oxygen ratio of 1:2. In the near pure state of only silicon and oxygen the mineral is quartz (SiO_2). But the tectosilicates are not that simple. It turns out that the aluminum ion can easily substitute for the silicon ion in the tetrahedrons up to 50%. In other subclasses this substitution occurs to a more limited extent but in the tectosilicates it is a major basis of the varying structures. While the tetrahedron is nearly the same with an aluminum at its center, the charge is now a negative five (-5) instead of the normal negative four (-4). Since the charge in a crystal must be balanced, additional cations are needed in the structure and this is the main reason for the great variations within this subclass. Below are the more common members of the tectosilicate subclass. See the **tectosilicates'** page for a more complete list.

- **The Feldspar Group:**
  - **Albite** *(Sodium Aluminum Silicate)*
  - **Andesine** *(Sodium Calcium Aluminum Silicate)*
  - **Anorthite** *(Calcium Aluminum Silicate)*
  - **Bytownite** *(Calcium Sodium Aluminum Silicate)*
  - **Labradorite** *(Sodium Calcium Aluminum Silicate)*
  - **Microcline** *(Potassium Aluminum Silicate)*
  - **Oligoclase** *(Sodium Calcium Silicate)*
  - **Orthoclase** *(Potassium Aluminum Silicate)*
  - **Sanidine** *(Potassium Aluminum Silicate)*
- **The Feldspathoid Group:**
  - **Cancrinite** *(Sodium Calcium Aluminum Silicate Carbonate)*
  - **Lazurite** *(Sodium Calcium Aluminum Silicate Sulfate Sulfide Chloride)*
  - **Leucite** *(Potassium Aluminum Silicate)*
  - **Nepheline** *(Sodium Potassium Aluminum Silicate)*
  - **Sodalite** *(Sodium Aluminum Silicate Chloride)*
- **The Quartz Group:** *(All Silicon Dioxide)*
  - **Coesite**
  - **Cristobalite**
  - **Quartz**
  - **Tridymite**
- **Scapolite** *(Calcium Sodium Aluminum Silicate Chloride Carbonate Sulfate)*
- **The Zeolite Group:**
  - **Analcime** *(Hydrated Sodium Aluminum Silicate)*
  - **Chabazite** *(Hydrated Calcium Aluminum Silicate)*
  - **Harmotome** *(Hydrated Barium Potassium Aluminum Silicate)*
  - **Heulandite** *(Hydrated Sodium Calcium Aluminum Silicate)*
  - **Laumontite** *(Hydrated Calcium Aluminum Silicate)*
  - **Mesolite** *(Hydrated Sodium Calcium Aluminum Silicate)*
  - **Natrolite** *(Hydrated Sodium Aluminum Silicate)*
  - **Phillipsite** *(Hydrated Potassium Sodium Calcium Aluminum Silicate)*
  - **Scolecite** *(Hydrated Calcium Aluminum Silicate)*
  - **Stellerite** *(Hydrated Calcium Aluminum Silicate)*
  - **Stilbite** *(Hydrated Sodium Calcium Aluminum Silicate)*
  - **Thomsonite** *(Hydrated Sodium Calcium Aluminum Silicate)*

Back to the **top**
